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DDT in California Sea-Lions: A Follow-Up Study After Twenty Years

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Extraordinarily high levels of ΣDDT (p,p'-DDT + p,p'-DDD + p,p'DDE) have been reported previously in California sea-lions (*Zalophus californianus californianus*) collected on the central California coast in the early 1970s (Le Boeuf & Bonnell, 1971). We now report a decrease of over two orders of magnitude in ΣDDT levels in California sea-lions between 1970 and 1992. In no other wildlife population has such a large decline in residue levels been reported (Loganathan & Kannan, 1991). As with brown pelicans (*Pelecanus occidentalis*), this decline in levels is attributed to the cessation of the release of DDT residues by the Montrose Chemical Corporation (Anderson *et al.*, 1975). The decline in residue levels in California sea-lions over this period is accompanied by a significant increase in the population during the same time period.

Blubber tissue was collected from fresh carcasses of sub-adult and adult male sea-lions found on beaches between Año Nuevo Point in San Mateo County and the Pajaro River mouth in Santa Cruz County, California, between April 1988 and July 1992. The blubber samples weighed 40–50 g, and were frozen immediately. The samples were extracted with CH_2Cl_2:hexane (1 : 1), fractionated and analysed by dual column high resolution gas chromatography. A detailed description of the method can be found in Jarman *et al.* (1993). Levels are reported in mg kg^{-1} wet weight, as geometric means.

The mean level of ΣDDE for adult and sub-adult male California sea-lion samples in the present work was 5.0 mg kg^{-1} ($n = 7$), compared to 740 mg kg^{-1} for 12 sea-lion samples in 1970 (Table 1). This is a significant ($p < 0.0001$) decline of over two orders of magnitude. p,p'-DDE and p,p'-DDT were found in all samples from both studies. A small amount of p,p'-DDD may also have been present in some or all of the samples, but could not be quantified because of co-elution with *cis*-nonachlor (the p,p'-DDD concentrations for both data sets are considered negligible with respect to the ΣDDT value).

Addison (1989), in a review of organochlorine and marine mammal reproduction, suggested that the levels of ΣDDT reported in 1971 might be artificially high due to co-elution with PCB compounds. The main interference of PCBs with the quantification of DDT compounds in marine mammals is the co-elution of p,p'-DDT with PCBs (Risebrough, 1969). The 1970 data did not show an abnormally high DDT:DDE ratio (Table 1) and the high levels of ΣDDT were similar to

TABLE 1

Geometric mean levels of DDE, DDT, and the ratio of DDT/DDE(×100) in male California sea-lion blubber, with a range of one SD in parentheses. Residue values are expressed as mg kg^{-1} wet wt.

1970*			1988–1992		
DDE	DDT	DDT/DDE	DDE	DDT	DDT/DDE
740 (370–1500) $n = 12$	17 (8.3–34)	0.023	5.0 (2.5–10) $n = 7$	0.16 (0.07–0.35)	0.032

*1970 data were originally reported as arithmetic means (Le Boeuf & Bonnell, 1971).

those reported for brown pelicans (both species are piscivorous) nesting in the Channel Islands during the same time period (Anderson *et al.*, 1975).

Studies of the temporal levels of DDT compounds in wildlife from other geographic 'hot spots' such as the Great Lakes (Environment Canada, 1991), the Baltic Sea (Blomkvist *et al.*, 1992; Kannan *et al.*, 1992; Bignert *et al.*, 1993), and the Wadden Sea (Buther, 1990) have reported declines of ΣDDT of approximately one order of magnitude since the late 1960s or the early 1970s (Loganathan & Kannan, 1991). The sole exception to this decline of one order of magnitude is from a temporal study of organochlorine residues in lizard gobys (*Rhinogobius flumineus*) from the River Nagarawa, Japan, that reported a decline in DDT residues of over two orders of magnitude, but this concentration decrease was based on a single-sample comparison (Loganathan *et al.*, 1989).

The current ΣDDT levels in California sea-lion blubber are similar to those found in the blubber of harbour seals (*Phoca vitulina vitulina*) from the west coast of Sweden, but higher than in grey seals (*Halichoerus grypus*) from the north-east coast of Scotland collected in 1988 (1.7 and 7.3 mg kg^{-1} wet wt, respectively; see Blomkvist *et al.*, 1992).

Male California sea-lions tend to migrate to the Channel Islands and islands off of the coast of Baja California for the annual breeding season in May–August (Peterson & Bartholomew, 1967). Sea-lions are most abundant near the Channel Islands rookeries and in the north and central waters of the southern California Bight (Le Boeuf *et al.*, 1983), where they feed opportunistically on a variety of prey species (Antonelis *et al.*, 1984).

The extremely high ΣDDT concentrations reported in the 1970s have been associated with reproductive problems in California sea-lions (DeLong *et al.*, 1973; Gilmartin *et al.*, 1976). California sea-lion census data collected on the Channel Islands in 1975 and 1993 show a population increase of over 133% during this 18-year period. Total pup counts for San Nicolas, San Miguel, Santa Barbara and Santa Cruz Islands increased from approximately 12 000 in 1975 to 28 000 in 1993 (Mark S. Lowry, National Marine Fisheries Service, pers. comm.).

The Southern California Bight was subjected to the continuous disposal of commercial DDT by the Montrose Chemical Corporation through sewage outfalls from 1949 to 1970. An estimated 91 t of DDT compounds were released into the ocean each year during this 20-year period (MacGregor, 1974, 1976). Declining DDE residues and a corresponding increase in the brown pelican population of the Channel Islands have been attributed to the cessation of this DDT discharge (Anderson *et al.*, 1975). It appears that the decline in ΣDDT residues in California sea-lions has been so dramatic because the sea-lion breeding area in Southern California is presently much less contaminated with DDT residues than in 1970. The decrease in ΣDDT residues in California sea-lions is associated with the observed population increase, but a cause–effect link has not yet been unequivocally established.

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